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STUDY and REPRESANTATION of the λ - ρ -T SURFACE for the PENTAFLUOROETHANE (REFRIGERANT R125) in the REGULAR REGION 1

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ABSTRACT

New thermal conductivity measurements were conducted on pentafluoroethane using the coaxial cylinders steady and unsteady methods. This systems have been thoroughly examined over the two past decades by thermal conductivity measure ments of the carbon dioxide, refrigerants R12, R22, R115, R134a, R125, their mixtures, argon and toluene. Experiments were conducted with a carefully prepared sample of R125 (purity of 99.85%). The thermal conductivity points were observed over the temperature range of 172 to 419 K and the pressures ranged from 0.1 to 9.0 MPa.

Thermal conductivity was represented as the sum of two terms of a low-density contribution and a density-dependent term, so-called excess thermal conductivity. A correlation which represent the λ - ρ -T surface of pentafluoroethane in the regular region is tested. A representative comparison between the experimental values and those correlated by the background thermal conductivity expression is examined.

KEY WORDS: refrigerant, pentafluoroethane, R125, coaxial cylinders method, thermal conductivity, λ - ρ -T surface, regular region.

1. INTRODUCTION

Some of the advantages of using of HFCs (hydrofluorocarbons) as a safe refrigerant or foam flowing agent have been pointed out and discussed in the literature [1]. Among these candidates for the replacement of HCFC-22 or HCFC-502 pentafluoroethane (HFC-125) has a zero ozone depletion potential. It is also found to be reasonably stable, inflammable, chemically inert to most usual metals, plastic materials, and elastomers used in industry. The pentafluoroethane is already in commercial production and is used in refrigerant blends for refrigerarion and air-conditioning.

In various applications the relationship among the thermal conductivity, temperature, and pressure from the gas to the liquid state should be known accurately for the purposes of equipment design. This paper presents information on the thermal conductivity of the HFC-125 at a wide range of temperatures from 172 to 419 K, pressures from 0.1 to 9.0 MPa, and densities up to 1700 kg·m $^{-3}$.

2. EXPERIMENTAL METHOD

The method, apparatus and procedure used to measure the thermal conductivity of HFC-125 have been described in detail in our previous publications [2,3].

The measurements were carried out with the vertical coaxial cylinders method, operating in the steady-state mode and in the transient mode. The transient coaxial cylinders

measurements were carried out in the region between 172 and 290 K. The second dataset was obtained between 280 and 419 K by the steady-state method.

The sample fluid was restricted in the annualar gap of 0.265 mm for the transient cell and in the gap of 0.220 mm for the steady-state apparatus.

The temperature difference ΔT across the fluid layer was measured with differential thermocouples and to avoid laminar convection the limiting values of ΔT were found of about 2-3 K for the liquid state and of 5-10 K in the gaseous phase.

This apparatus was used previously to measure the thermal conductivity of toluene, argon, carbon dioxide, refrigerants CFC-12 (R12), HCFC-22 (R22), CFC-115 (R115), and HFC-134a (R134a). Based on the analysis of error sources [2, 3] and reproductibility of the measurements, the uncertainties of the experimental points for the pentafluoroethane are estimated to be within ± 2 to ± 4 %.

3. EXPERIMENTAL RESULTS

The purity of the sample of the pentafluoroethane used for the thermal-conductivity measurements supplied by State Institute of Apllied Chemistry (GIPCh) is 99.85 wt%. The present experimental results for the thermal conductivity of HFC-125 are shown in Table I. The current data points

are at pressures between 0.1 and 8.6 MPa and at temperatures between 172 and 419 K.

The experimental data were analyzed using the equation of state presented in our earlier publication [4].

4. DATA ANALYSIS

It was used the correlating technique based on the excess thermal conductivity concept. From own and other available experimental data [5] were derived quasi dilute-gas values represented by an empirical expression of the form

$$\lambda^* = 7.200 \cdot 10^{-4} + 1.227 \cdot 10^{-5} T + 1.1407 \cdot 10^{-7} T^2, \tag{1}$$

where λ^* is in $W \cdot m^{-1} \cdot K^{-1}$ and T is temperature in Kelvin.

Eq. (1) represents the experimental information for thermal conductivity with an standard deviation of about $\pm 3\%$ at temperatures from 236 to 420 K.

The terms of residual thermal conductivity were based on the our data in the vapor phase [4] and in the liquid phase including reported in present work new measurements. The excess thermal conductivity was represented with the four-parameter expression [4]

$$\Delta \lambda / H = \exp(S)$$
. (2)

As for refrigerants R22, R12, and R50 [3] the temperature dependance of excess thermal conductivity of penta-fluoroethane is only weakly on temperature however it was found useful to include the parameter S defined as $\omega \tau^{0.05}$.

The factor H was defined as

$$H = e_1/(e_2 + e_3S^n).$$
 (3)

Reduced density $\omega=\rho/\rho_C$ and reduced temperature $\tau=T/T_C$ are independent variables. Critical parameters are $T_C=339.35~\rm K~(ITC-90)$ and $\rho=572~\rm kg\cdot m^{-3}~[4]$, $\Delta\lambda$ in $W\cdot m^{-1}\cdot K^{-1}$. The parameter values in Eq. (3) are $e_1=0.018868$, $e_2=3.00722$, $e_3=0.21114$, n=-2.03644. Eq. (2) is valid for the regular region of the $\lambda-\rho-T$ surface in the temperature range from 172 to 419 K and up to 1700 kg·m⁻³.

The correlation (2) represents our data satisfactory within the estimated accuracy. The Fig. 1 shows percent deviations versus density of the representation of the our dataset by Eq. (2). Fig. 2 shows deviations of the experimental datasets obtained by other investigators [6-10].

The diviation plots shown in Fig.1 and Fig. 2 reveals un average absolute deviation of the correlation (2) that varies from about 4% in the vapor phase to about 3% in the liquid region.

We have also calculated for pentafluoroethane the values for the thermal conductivity from Eqs. (2) and (3), and Tables II contains the properties as a function of temperature for the liquide and the vapor side of the coexistance curve.

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Table I. Experimental results for the thermal conductivity of HFC-125ª

			404.2
T	P	ρ -3\	$10^4 \lambda$
(K)	(MPa)	$(kg \cdot m^{-3})$	$(\mathbf{W} \cdot \mathbf{m}^{-1} \cdot \mathbf{K}^{-1})$
172.51	1.15	1688	1116
174.73	1.16	1682	1106
187.43	5.21	1652	1075
191.39	6.04	1641	1065
199.02	1.18	1605	1012
200.93	4.41	1608	1025
206.95	3.32	1585	1000
209.47	3.37	1577	989
214.50	4.85	1557	979
217.20	1.19	1542	948
223.22	4.31	1529	946
231.79	3.90	1500	906
240.63	3.57	1468	870
241.09	0.13	8.13	102
245.66	1.23	1441	841
251.88	3.25	1426	834
253.13	0.23	14.0	111
265.06	2.99	1372	780
269.71	1.17	1341	747
275.58	6.15	1341	756
283.86	5.11	1301	723
290.02	1.23	1239	680
291.57	1.16	1227	684*
296.23	3.06	1230	671
297.08	1.90	1211	672*
297.94	4.39	1231	670
299.47	6.74	1238	688*
299.62	2.59	1207	634*
300.36	1.54	1180	648*
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Table I. Continued

T	Р	ρ	10 ⁴ λ
(K)	(MPa)	$(\text{kg} \cdot \text{m}^{-3})$	$(\mathbf{W} \cdot \mathbf{m}^{-1} \cdot \mathbf{K}^{-1})$
300.32	2.15	1196	662*
300.86	2.14	1192	666*
302.64	4.56	1209	678*
302.66	3.155	1197	669*
302.85	3.25	1199	672*
304.35	4.17	1197	649
304.54	1.80	1160	651*
305.30	3.73	1188	636*
306.17	0.34	16.8	153
314.60	3.94	1136	618
317.74	5.78	1136	621*
317.79	5.055	1130	586*
318.39	3.15	1098	565 *
321.18	3.59	1087	592
323.30	3.18	1061	576 *
324.62	4.56	1079	602*
325.55	6.26	1093	567*
326.05	6.95	1097	619 *
329.37	2.65	192	219*
330.04	0.34	15.4	172
334.98	4.25	991	516 *
335.49	1.31	65.8	178 *
338.88	8.58	1028	556*
346.78	8.24	964	530 *
366.52	2.45	120.5	232*
378.12	1.44	6.09	231*
419.38	1.45	53.4	268∗

^a Values with an asterisk superscript were measured by steady-state method. Values without an asterisk measured by transient coaxial-cylinder method.

Table II. Saturation properties of HFC-125 (single prime indicate saturated liquid, double prima indicate saturated vapour)

T	Р	ρ'	ρ''	10 ⁴ λ	10 ⁵ λ
(K)	(MPa)	(kg·m ⁻³)	$(kg \cdot m^{-3})$	$(W \cdot m^{-1} \cdot K^{-1})$	$(\mathbf{W} \cdot \mathbf{m}^{-1} \cdot \mathbf{K}^{-1})$
213.15	0.0544	1555	3.79	970	852
223.15	0.0922	1520	6.22	929	915
233.15	0.1484	1483	9.73	889	980
243.15	0.2281	1445	14.64	849	1050
253.15	0.3374	1406	21.32	811	1125
263.15	0.4825	1364	30.24	773	1207
273.15	0.6705	1320	41.99	732	1301
283.15	0.9087	1272	57.38	693	1413
293.15	1.2050	1219	77.62	654	1551
303.15	1.5682	1160	104.7	612	1723
313.15	2.0084	1090	142.1	568	1939
323.15	2.5374	1002	197.8	518	2209
333.15	3.1712	870	297.1	4 53	2579

FIGURE CAPTIONS

- Fig. 1. Percentage deviations of our experimental data for the thermal conductivity of HFC-125 from the values calculated with the correlation, eqs. (2,3).
- Fig. 2. Percentage deviations of experimental data sets for the thermal conductivity of HFC-125 of other investigators from the values calculated with eqs.(2,3). (\bigcirc) Ref.8; (\triangle) Ref.7; (\otimes) Ref.10; (\square) Ref.9.



